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A Community-Based Diabetes Prevention and Management Education Program in a Rural Village in India

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ABSTRACT

Objective: This study evaluates a 7-month community-based non-pharmacological lifestyle intervention to prevent/reduce the risk of developing diabetes and its complications in a resource-poor village in Tamilnadu, India.

Research Design and Methods: Seven hundred and three village inhabitants, comprising of adults and youth 10 - 92 years of age were provided educational intervention using 'trained trainers'. Culturally and linguistically appropriate health education messages addressed diet, physical activity and knowledge improvement. The prevalence of diabetes mellitus and the effectiveness of the intervention were assessed using select parameters.

Results: The crude prevalence of diabetes and pre-diabetes among adults was 5.1% and 13.5% respectively, while pre-diabetes in youth 10-17 years of age was 5.1%. Intervention reduced fasting blood glucose levels of pre-diabetes adults by 11%, pre-diabetes youth by 17% and among adults with type 2 diabetes mellitus by 25%. Improvements in obesity parameters and dietary intake also occurred. A step-wise worsening of parameters progressing from the normoglycemic state to the impaired levels of pre-diabetes and Diabetes mellitus was observed.

Conclusions: This study has charted the increasing prevalence of diabetes and pre-diabetes in rural India. Educational intervention was successful in reducing some of the obesity parameters and improving dietary patterns of individuals with pre-diabetes and diabetes mellitus.

India has the dubious distinction of having the highest prevalence of diabetes mellitus worldwide (1-3). Further, the number of individuals with diabetes mellitus will reach 79.4 million by 2030 with earlier age manifestations (1,2,4). Approximately 70% of India's population lives in rural areas (2) in resource-poor settings where the increasing prevalence and chronic nature of Type 2 Diabetes Mellitus (T2DM) become added burdens (5). Lack of awareness and poor access to quality care increase diabetes-related complications (5).

Lifestyle intervention is the most cost-effective strategy to prevent T2DM (5,6). However there have been few well-designed studies in rural settings that have shown successful intervention in improving awareness and lifestyle changes. The purpose of this community-based program was to (1) assess the prevalence of T2DM and pre-diabetes and (2) evaluate the effectiveness of a non-pharmacological lifestyle intervention aimed at reducing risk factors and improving disease self-management. The Diabetes Prevention and Management (DPM) program was designed to increase awareness at the grass-roots level using the inclusive environment of a whole village with a population-based approach (7). Simple and practical lifestyle modifications were customized to educate the village inhabitants on T2DM risk factors and self-care.

RESEARCH DESIGN AND METHOD

The study used a collective population approach. The duration of the study was from October 2002 to April 2003. The village of Alamarathupatti, one of the field sites of Gandhigram Rural Institute (GRI), was selected. This village had a population of 950 residents ≥ 10 years of age and of mixed socio-economic strata (Table 1).

An initial participatory rural analysis of the village enabled the involvement of the village leaders, peer educators, and residents in the planning and implementation phases of the project and served to highlight resources and requirements. Trained individuals carried out data collection and educational intervention. Face-to-face interviews were considered the most appropriate method since 41% of respondents had less than 5th grade education. The study was approved by the Institutional Review Board of Texas A & M University's and written informed consent was obtained from all participants.

Sample Size. Although 850 residents participated in the baseline survey, 703 individuals, 118 youth 10 – 17 years & 585 adults, completed the post-intervention survey questionnaire resulting in a response rate of 74%; attrition rate due to migrations and refusals was 17%. Recruitment of respondents was completed through door-to-door visitations. There were two data collection points for the study i.e., baseline and post-intervention collected by trained personnel. No monetary compensation was provided but health appraisal data was disseminated to the participants.

Measurements. Demographic characteristics included a personal/family history of diabetes, educational level, income, diet pattern, and smoking/alcohol intake. Due to a marked resistance among the village inhabitants towards venous blood drawing, capillary blood glucose values were used to assess the prevalence of T2DM and pre-diabetes as used in a rural study by Chow (8). Fasting blood glucose (FBG) testing was conducted using the Accu-check glucometer and individuals with impaired FBG were reconfirmed. Normoglycemic levels (NGL), impaired fasting glucose (IFG), and diabetes levels were established according to the revised ADA standards of care (9). Anthropometric data included height, weight, hip, waist, and thigh measurements. Height and weight were measured by standard procedures. Waist circumference (WC) was taken at the level of the last rib to the nearest 0.1 inches after a

normal expiration. Hip circumference (HC) was taken at the maximum extension of the buttocks as viewed from the side. Thigh circumference (ThC) was measured at the proximal right thigh directly below the gluteal fold(10). BP was measured by sphygmomanometry to the nearest mm Hg, in the left arm, seated, after 10 minutes rest, and validated with a repeated periodic measure on the same individual and a third time if the two readings were >4 mm Hg apart when a mean value was taken. Body Mass Index (BMI) and waist-hip-ratio (WHR) were calculated and reference guidelines for Asian Indians were used for all obesity measures (11,12).

Occupation levels for adults and scheduled physical activity at school for children were surrogate measures to calculate physical activity. A 24-hour dietary recall assessed diet and macronutrient consumption (carbohydrate, protein, fat, fiber, and total kilocalories) using the National Institute of Nutrition guidelines for Indian foods (13). Knowledge of foods was assessed by a 10-item questionnaire with response options as true (1) or false (0). Results of a principle components factor analyses with Varimax rotation indicated all scale items loaded on a single factor and accounted for 63% of the variance, thus supporting the validity for the scale. A knowledge score was computed by summing the correct answers, greater scores indicated higher knowledge; Cronbach's alpha was 0.85.

Educational Intervention. Key features of the DPM intervention included culturally-sensitive and linguistically appropriate (Tamil language) sessions on dietary modification (increasing fiber, reducing fat, and portion control), improving physical activity and stress-relaxation. Ten face-to-face encounters were provided to all respondents on a one-on-one basis with health messages tailored for gender, age and socio-economic differences. The topics included introduction to diabetes and their complications, diabetes prevention and , modifiable risk factors, healthy body weight, central adiposity and waist circumference, elevated blood pressure levels, physical activity, fiber rich wholesome foods, dietary behaviors, and stress relaxation. Reinforcement of education intervention was supported by group events. The 'core' group of individuals with impaired fasting blood glucose values was given additional counseling as needed.

Weight loss goals were not universally emphasized since 77% were normal/underweight. Dietary education focused on the intake of fiber and protein from local low-cost resources like the nutritionally-rich drumstick leaves, millets, legumes/lentils and whole grains. These were reinforced through cooking demonstrations, recipe competitions, and model meals. Further, avoidance of sweetened drinks and fried foods was emphasized. Physical activity was promoted and reinforced with demonstrations, competitive fun events and dancercise events for the younger respondents. Stress-relaxation included the importance of meditation and breathing exercises (familiar to many of the respondents). Education and counseling for blood glucose management was provided by a certified diabetes educator on a one-on-one basis to the high-risk group. These included the importance of periodic blood glucose testing, weight control, portion-controlled diet, regulated physical activity and medication management (where applicable). Low glycemic model meals demonstrated the substitution of polished white rice with millets, sprouted legumes and vegetables.

Trained Trainers. The trainers were science graduates and trained at GRI for 6 months and in tandem with the intervention. Training curriculum included knowledge of T2DM, its risk factors, meal-planning reinforced in the model kitchen, physical activity and non-confrontational interviewing and education techniques. Further, trainers underwent role-

play and interactive problem- solving sessions and were housed in the village for the duration of the project.

Statistical Analysis. Prevalence of diabetes and pre-diabetes was calculated from baseline survey. Basic descriptive statistics were obtained for demographic and study variables. Student t-test and Chi-square analysis (for categorical variables) evaluated pre- and post-intervention changes. Analysis of Covariance (ANCOVA) was used to examine significant post-intervention differences between NGL IFG, and T2DM with baseline scores used as covariates in the model. The acceptance level for statistical significance was lowered from 0.05 to 0.006 for the food variables and .007 for the body measures, a Bonferroni correction for multiple comparisons; statistical significance for the knowledge score was set at .05 . Hierarchical regression analysis was used to determine significant predictors of fasting blood glucose levels. Data analysis was performed using the Statistical Package for Social Science (SPSS – version 15.0) software.

RESULTS

The mean age of the respondents was 35.8 ±17 years (Table 1). The majority of respondents were adults (83.2%), females (51.7%), married (66%), and with an educational level of less than a high school diploma (66%). Approximately half (51%) were in the low socio-economic status (income less than Rs.3000 or $ 75.00/month) and 62% reported a sedentary lifestyle. Activity levels were lower among females (p=.001) and T2DM individuals (p=.08). Fifty-one percent of youth met the Surgeon General's recommendation for physical activity with higher levels among males (p=.03).

Prevalence of Diabetes. The crude prevalence of diabetes and IFG was 4.3% and 12.1% respectively. Age-specific prevalence of diabetes and IFG were 5.1% and 13.5% among adults and 0% and 5.1% IFG among youth. Gender-specific prevalence of diabetes and pre-diabetes among adults showed a significantly higher rate (χ^2 value = 12.37, p=.002) in males (6.2% diabetes and 19.0% pre-diabetes) than females (4.4% diabetes and 9.6% pre-diabetes). T2DM generally rose with age in both genders (p=.001), reaching 43.3% among 36-50 year age group and 50.0% among ≥50 age group.

Obesity Measures. Mean BMI in the adult population was 20.59 ± 3.82 and is in the normal range; 11.6% were overweight, and 16.4% were obese. There was a significant increase in the prevalence of IFG and T2DM with increasing BMI among adults (F-value 38.6, p=.001); this difference was not observed in youth. Although WC was low (74% in normal range), 59% had abnormal WHR (>0.81 for women and >0.89 for men). Both WHR (p=.003) and WC (p=.001) were significantly higher among males than females. Among the obesity parameters, the higher correlation was between WC and HC (r= 0.86 for men and r=0.76 for women) than HC and ThC (r= 0.69 for men and r= 0.73 for women) and WC and ThC (r=0.62 for men and 0.60 for women). ThC was strongly associated with BMI in both genders but had a moderate association with WHR and a weak association with FBG in men, not correlating in women.

The mean values of BMI, WC, and WHR for youth were 16.0± 2.72, 24.49± 2.98 inches and 0.84± 0.03 respectively. Female youth had higher WC (p=.002) and BMI (p=.001) but lower WHR (p=.025) as compared to their male peers; prevalence of IFG significantly correlated with central obesity (WC and WHR) among youth. WC, HC and ThC were strongly associated and followed adult patterns. However, ThC was not associated with WHR and FBG in either gender.

Dietary Intake. Mean caloric intake was 1636.1± 683.1 and 1370.5± 536.2 in adults and youth respectively; 14% of the study

population reported consuming less than 1000kcals per day. It must be noted that even among individuals with intakes less than 1000 Kcal (n=82), 8.1% had IFG and 6.3% had T2DM. Although males had significantly higher intakes of total calories than females (p=.001), no significant difference in calorie intake was noted by NGL, IFG, and T2DM groups (p=0.40). The majority of adult respondents had high carbohydrate consumption (approximately 80%) with 16% of calories coming from protein, and around 4% from fat intake. Carbohydrate consumption came mainly from white polished rice with sporadic use of refined wheat. Adults with T2DM had lowest carbohydrate but highest fat intake as compared to NGL and IFG groups (p=.001). Female respondents had lower intake of calories and macronutrients than males (p=.001). Nutrient consumption was similar for boys and girls in the youth group.

Hypertension. Prevalence of systolic and diastolic hypertension and pre-hypertension was significantly higher (p=.001) among males than females increasing with age (p=.001). There was a linear (significant) increase in systolic and diastolic blood pressure with the increase in respondents' blood glucose levels. Approximately one-fifth (17.4%) of the adult population had high blood pressure (≥140/90 mm/Hg; 23.6% males and 13.1% females). Among youth, 15.3% had systolic and diastolic pre- or hypertension values which did not vary by gender.

INTERVENTION

Intervention successfully reduced several risk factors among adults, youth, and high-risk groups of IFG and T2DM (Table 2). Intervention reduced FBG levels by 3% in the adults, 11% in IFG adults, 17% in IFG youth and 25% among adults with T2DM. A significant reduction in all obesity parameters was also noted among adults and IFG adults (significance ranging from .026 to .001). Diabetes management reduced WC (p=.039) and thigh circumference (p=.023) in T2DM adults. In youth, intervention lowered WC, HC, ThC, and WHR (p=.001) although BMI increased. Among IFG youth there was a reduction in FBG approaching significance (p=.014).

Significant improvements were noted dietary fiber and protein intakes among adults; protein & carbohydrate intake increased among IFG adults with improvements in fiber intake approaching significance (p=.011). Concomitantly, their diets showed an increased calorie intake (p=.001). Although no significant change in diet patterns was noted in youth except for a decrease in their protein intake (p=.011), there was an increase in the knowledge level approaching significance (p=.013). Systolic and diastolic blood pressure also reduced in adults, IFG adults, and youth. The greatest improvement was noted in the reduction of HC and lowest change in dietary nutrient consumption.

Differences in post-intervention parameters by groups showed that IFG and T2DM adults had significantly higher HC and ThC than their normoglycemic peers (Table 3). These respondents showed a higher knowledge of the disease (p=.006). Carbohydrate, protein, and total caloric intake were lowest among T2DM cases and highest among IFG. Differences (approaching significance) were also noted between the groups for BMI, WC, WHR, diastolic blood pressure, and total fiber intake (p=.02 to .07). The parameters of BMI and knowledge among IFG youth were higher than their normoglycemic counterparts.

Post-intervention dietary pattern was similar to the baseline data by gender. Adult males and youth showed higher intake of total calories, carbohydrate, protein, fat, and fiber intake than females. Additionally, they also had higher levels of FBG, blood pressure, and

obesity (WHR and WC). However, males had higher WHR, and females had higher ThC, BMI, and HC.

Predictors of FBG among adults indicated diastolic blood pressure as the most significant predictor (Beta = .20) followed by systolic blood pressure (Beta = .17) and dietary fiber intake (Beta = .15) in the regression model; BMI and ThC approached significance (p=.07 and .08 respectively). In other words, respondents who had a lower fiber intake, higher blood pressure, BMI and ThC had higher blood glucose levels. These five variables explained 14% of the variance (F=4.54, p=.001). Among high-risk individuals, FBG was predicted by fiber intake and diastolic blood pressure (R^2 = .23, F=1.86, p=.03). Significant predictors in youth included general and abdominal obesity (WC and BMI) as well as a higher carbohydrate/fat intake; 31% of the variance was accounted by these variables (F=2.41, p=.003).

DISCUSSION

This population study showed a higher prevalence of T2DM and IFG in an agrarian community (despite low BMI) than earlier studies (2,14). Further, T2DM was observed at a younger age than earlier reports (2, 4,14) affirming the World Health Organization predictions (1). Although a higher prevalence of T2DM among males and older individuals was expected (8), there is a concerning prevalence of IFG in youth (15).

Over 11% of the illiterate population with IFG or T2DM were in the low-income groups confirming that glucose impairment is not only 'a rich man's disease' but also impacts the rural poor. The poorest villagers suffered from a lack of knowledge and inadequate access to health care. These factors allow the deterioration of the glycemic status while this metabolic disease is still silent. Declining agrarian employment among adults and less sports/physical activity in youth coupled with television-viewing and labor-saving devices may collectively contribute to increasing physical inactivity although physical activity was not accurately measured in the present study. A lower income has steered this population towards the use of subsidized white polished rice as a major component (80%) of the diet in lieu of higher-priced legumes, vegetables and millets. However, the increased fiber intake suggests their health benefits had been accepted.

The lifestyle modifications were effective in reducing some of the risk factors for T2DM and improved self-management of the disease. With the escalating rate of T2DM disproportionately affecting Indians (2), education of vulnerable communities can become a cost-effective public health strategy. It has been shown self-care among individuals with T2DM improved glycemic control and reduced complications (16). Indians seem to have a genetic predisposition towards insulin resistance with a low BMI and high central adiposity - Yudkin-Yajnik paradox (17-19). This study observed relatively low BMI and WC but high WHR among adults (2,20-22). Approximately 2/3rd of the respondents had abnormal WHR but did not classify under abnormal WC or BMI levels even with Asian standards of classification suggesting that rural Indians of thin stature may require lower WC standards to measure central adiposity. Comparison of obesity between youth in this study and urban adolescents in New Delhi showed a lower WC and BMI for rural youth but a higher WHR (12). In keeping with other successful lifestyle modification studies (16,23), our intervention proved that lifestyle modifications can be successfully implemented in larger-based community settings in rural India. Future studies of population-based DPM programs in other sites should assess its cost-effectiveness and replicability.

This is the first study to measure ThC among rural Indians but lack of standards for the smaller stature Asian Indians prevents a comparison with the Hoorn Study (24). Studies have shown an association between thigh measurements and FBG that is corroborated for adult males only (24) with a lower ThC predicting increased risk for glucose intolerance (10). The DPM's emphasis on walking may have contributed to decreased ThC (due to the low caloric intakes) and is a concern due to the association of these measures with incident diabetes (24).

DPM intervention emphasizing physical activity/stress relaxation/dietary changes successfully reduced systolic (4% drop) and diastolic blood pressure (11% drop) among pre-diabetes adults thereby reducing their risk for heart disease (25). However, the presence of hypertensive levels of blood pressure with elevated blood glucose suggests the synergistic influence of co-morbidities (26). Prior studies have also shown lifestyle modification successfully reduced hypertension (6, 16). We speculate that intervention successfully affected hypertension levels among IFG adults but not youth due to a wide window for impact, higher levels, and a larger sample size. The high rates (40%) of hypertension and pre-hypertension prevalent in an agricultural community call for aggressive attention due to their causative links with cardiovascular disease, stroke, renal dysfunction, and mortality, conditions that are increasing in the Indian population (27,28).

Increase in the intake of carbohydrate was observed for adults with a greater increase among IFG adults. This may be due to lack of controlled eating and should be emphasized in future studies. Model meals served as a valuable interactive tool and demonstrated that mixing of millets and legumes can stretch nutrient density (13). The major component of refined white rice, corroborated by earlier studies (13) with a low fiber intake could be a factor in post-prandial glucose overload (29). Although dietary education improved fiber intake, it was much lower than the recommended levels of over of 25 grams/day. The initial level of fat intake was very low (<5% of calories) and hence less likely to be affected by dietary intervention.

Use of fasting capillary blood values, instead of serum, in the study may have impacted the prevalence figures but findings are lower than those in the rural Andhra Pradesh study that also used the same method (8). Correlation of capillary and serum blood glucose values was high ($r=.81$, $p<.001$)

In conclusion, this population intervention program successfully reduced some of the obesity risk factors and improved FBG levels and fiber intake. The findings highlight the need to initiate preventive education in elementary schools as intervention helped to reduce IFG by 17%. Our results, if sustained in the future suggest that the incidence of T2DM may be delayed or prevented and its course changed for improved outcomes among vulnerable population groups (30).

REFERENCES

1. King, H., R.E. Aubert, and W.H. Herman, *Global burden of diabetes, 1995-2025: prevalence, numerical estimates, and projections.* Diabetes Care, 1998. **21**(9): p. 1414-31.
2. Ramachandran, A., et al., *Temporal changes in prevalence of diabetes and impaired glucose tolerance associated with lifestyle transition occurring in the rural population in India.* Diabetologia, 2004. **47**(5): p. 860-5.
3. Zimmet, P., K.G. Alberti, and J. Shaw, *Global and societal implications of the diabetes epidemic.* Nature, 2001. **414**(6865): p. 782-7.
4. Wild, S., et al., *Global prevalence of diabetes: estimates for the year 2000 and projections for 2030.* Diabetes Care, 2004. **27**(5): p. 1047-53.
5. *The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. The Diabetes Control and Complications Trial Research Group.* N Engl J Med, 1993. **329**(14): p. 977-86.
6. *Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). UK Prospective Diabetes Study (UKPDS) Group.* Lancet, 1998. **352**(9131): p. 837-53.
7. Satterfield, D.W., et al., *Community-based lifestyle interventions to prevent type 2 diabetes.* Diabetes Care, 2003. **26**(9): p. 2643-52.
8. Chow, C.K., et al., *The prevalence and management of diabetes in rural India.* Diabetes Care, 2006. **29**(7): p. 1717-8.
9. American Diabetes Association, *Standards of Medical Care for patients with Diabetes Mellitus.* . Diabetes Care, 2005. **26**: p. S33-S50
10. Kuk, J.L., P.M. Janiszewski, and R. Ross, *Body mass index and hip and thigh circumferences are negatively associated with visceral adipose tissue after control for waist circumference.* Am J Clin Nutr, 2007. **85**(6): p. 1540-4.
11. Chamukuttan, S., V. Viswanathan, and A. Ramachandran, *Cut-off values for Normal Anthropomatric Variables in Asian Indian Adults.* Diabetes Care, 2003. **26**: p. 1380-1384.
12. Misra, A., et al., *Simple anthropometric measures identify fasting hyperinsulinemia and clustering of cardiovascular risk factors in Asian Indian adolescents.* Metabolism, 2006. **55**(12): p. 1569-73.
13. Gopalan, C., et al., *Nutritive value of Indian foods.* 1989, Hyderabad, India.: Natioanl Institute of Nutrition, ICMR. .
14. Sadikot, S.M., et al., *The burden of diabetes and impaired glucose tolerance in India using the WHO 1999 criteria: prevalence of diabetes in India study (PODIS).* Diabetes Res Clin Pract, 2004. **66**(3): p. 301-7.
15. Pinhas-Hamiel, O., et al., *Increased incidence of non-insulin-dependent diabetes mellitus among adolescents.* J Pediatr, 1996. **128**(5 Pt 1): p. 608-15.
16. Ramachandran, A., et al., *The Indian Diabetes Prevention Programme shows that lifestyle modification and metformin prevent type 2 diabetes in Asian Indian subjects with impaired glucose tolerance (IDPP-1).* Diabetologia, 2006. **49**(2): p. 289-97.
17. Yajnik, C.S., *Early life origins of insulin resistance and type 2 diabetes in India and other Asian countries.* J Nutr, 2004. **134**(1): p. 205-10.
18. Goodpaster, B.H., et al., *Obesity, regional body fat distribution, and the metabolic syndrome in older men and women.* Arch Intern Med, 2005. **165**(7): p. 777-83.

19. Banerji, M.A., et al., *Body composition, visceral fat, leptin, and insulin resistance in Asian Indian men.* J Clin Endocrinol Metab, 1999. **84**(1): p. 137-44.
20. Neel, J.V., A.B. Weder, and S. Julius, *Type II diabetes, essential hypertension, and obesity as "syndromes of impaired genetic homeostasis": the "thrifty genotype" hypothesis enters the 21st century.* Perspect Biol Med, 1998. **42**(1): p. 44-74.
21. Mohan, A., et al., *Visceral and Central Abdominal Fat and Anthropometry in relation to Diabetes in Asian Indians.* . Diabetes Care 2004. **27**(12): p. 2948-2953.
22. Misra, A. and N.K. Vikram, *Insulin resistance syndrome (metabolic syndrome) and obesity in Asian Indians: evidence and implications.* Nutrition, 2004. **20**(5): p. 482-91.
23. Fujimoto, W.Y., et al., *Body size and shape changes and the risk of diabetes in the diabetes prevention program.* Diabetes, 2007. **56**(6): p. 1680-5.
24. Snijder, M.B., et al., *Larger thigh and hip circumferences are associated with better glucose tolerance: the Hoorn study.* Obes Res, 2003. **11**(1): p. 104-11.
25. Joshi, P., et al., *Risk factors for early myocardial infarction in South Asians compared with individuals in other countries.* Jama, 2007. **297**(3): p. 286-94.
26. Wylie-Rossett, J., *Hypertension and Diabetes: Clinical Synergy and Challenges.* On the Cutting Edge. DCE-American Dietetic Association, 2004. **25**(1): p. 1-10.
27. Chow, C.K., et al., *Significant lipid, adiposity and metabolic abnormalities amongst 4535 Indians from a developing region of rural Andhra Pradesh.* Atherosclerosis, 2007.
28. Singh, R.B., et al., *Prevalence of type 2 diabetes mellitus and risk of hypertension and coronary artery disease in rural and urban population with low rates of obesity.* Int J Cardiol, 1998. **66**(1): p. 65-72.
29. Englyst, H.N., J. Veenstra, and G.J. Hudson, *Measurement of rapidly available glucose (RAG) in plant foods: a potential in vitro predictor of the glycaemic response.* Br J Nutr, 1996. **75**(3): p. 327-37.
30. Newby, P.K., et al., *Dietary patterns and changes in body mass index and waist circumference in adults.* Am J Clin Nutr, 2003. **77**(6): p. 1417-25.

TABLE 1. Demographic Characteristics of the Respondents

	Total Sample†	*Adults 18 years and older*			*Youth < 18 years of Age*		
Characteristic	***(n=703)***	***Male (n=242; 41%)***	***Female (n=343; 59%)***	***Total (n=585; 83.2%)***	***Male (n=57; 48%)***	***Female (n=61; 52%)***	***Total n=118(16.8%)***
Age – yrs	35.8±17.0	42.5±15.2	38.8±15	40.3±15.1	13.5±1.9	13.9±2.2	13.68±2.0
18-20 years	43(7.4%)	11(4.5%)	32(9.3%)	43(7.4%)	0(0%)	0)0%)	0(0%)
21-65 years	506(86.5%)	213(88.0%)	293(85.4%)	506(86.5%)	0(0%)	0)0%)	0(0%)
> 65 years	36(6.2%)	18(7.4%)	18(5.2%)	36(6.2%)	0(0%)	0)0%)	0(0%)
Weight (Kg)	46.7±14.2	52.4±14.9	46.9±12.3	49.2±13.7	32.1±9.2	35.5±9.1	34.0±9.2
Body Mass Index	19.8±4.0	20.5±3.6	20.7±4.0		15.1±1.9	16.9±3.1	16.01±2.7
Underweight (BMI < 18.5)	304 (43.2)	82 (33.9%)	121 (35.3%)	203 (34.7%)	54(94.7%)	47(77.0%)	101(85.6%)
(BMI 18.5-22.9)	234 (33.3)	99 (40.9%)	119 (34.7%)	218 (37.3%)	3(5.3%)	13(21.3%)	16(13.6%)
Overweight (BMI 23-24.9)	68 (9.7)	29 (12.0%)	39 (11.4%)	68 (11.6%)	0.0(0.0%)	0.0(0.0%)	0.0(0.0%)
Obese (BMI ≥ 25.0)	97(13.8)	32 (13.2%)	64 (18.7%)	96(16.4%)	0.0(0.0%)	1(1.6%)	118(100.0%)
Waist Circumference	28.9±4.4	31.1±3.8	28.9±4.1	29.8±4.1	23.6±2.5	25.3±3.2	24.49±2.9
Normal		203(83.9)	230(67.1)	433(74.0)	na	na	na
Abnormal (M>35; F> 31in)		39(16.1)	113(16.1)	152(26.0)	na	na	na
Hip Circumference	33.7±4.1	34.0±2.9	35.1±3.9	34.65±3.5	27.7±2.7	30.5±3.4	29.14±3.38
Thigh Circumference	17.2±2.3	17.5±2.0	17.6±2.3	17.58±2.2	15.0±1.9	15.6±1.8	15.32±1.85
Waist-hip-ratio	0.86±.08	0.9±0.1	0.8±0.1	0.86±.08	0.9±0.1	0.8±0.1	.84±.05
Normal		82(33.9)	158(46.1)	240(41.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Abnormal(M>.89; F>.81)		160(66.1)	185(53.9)	345(59.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Capillary glucose -mg/dl							
In the fasting state*	92.2±42.5	97.6±39.7	92.2±50.1	94.4±46.1	82.2±10.7	80.6±8.6	81.3±9.6
Prevalence of Diabetes	4.3%	6.2%	4.4%	5.1%	0.0%	0.0%	0.0%
Prevalence of IFG	12.1%	19.0%	9.6%	13.5%	7%	3.3%	5.1%
Post prandial state**	120.2±49.0	128.7±54.7	119.5±50.9	123.3±52.7	106.4±17.2	103.6±18.0	104.9±17.6
Blood pressure -mm/Hg							
Systolic blood pressure	119.3±17.2	125.2±16.9	119.5±16.9	121.8±17.1	103.7±11.2	109.5±10.7	106.7±11.2
% Pre-hypertension	37.7%	44.2%	45.8%	41.7%	12.3%	23.0%	17.8%
% Hypertension	15.5%	24.8%	39.9%	18.6%	0	0	0
Diastolic blood pressure	83.3±15.1	89.0±15.1	83.0±14.8	85.5±15.2	71.3±8.1	74.0±10.0	72.7±9.2
% Pre-hypertension	28.9%	29.3%	26.5%	27.7%	33.3%	36.1%	34.7%
% Hypertension	39.4%	53.7%	40.2%	45.8%	1.8%	13.1%	7.6%

Education							
Illiterate	179 (25.5)	35 (14.5)	142 (41.4)	177±30.3	1 (1.8)	1 (1.6)	2±1.7
Up to primary education	108 (15.4)	42(17.4)	53(15.5)	95±16.2	6(10.5)	7(11.5)	13±11.0
High school Some College/Graduate	356 (50.6) 60 (8.5)	132(54.5) 33 (54.5)	124(36.2) 24 (7.0)	256±43.8 57±9.7	48(84.2) 2 (3.5)	52(85.2) 1 (1.6)	100±84.7 3±2.5
Income	1438.6±1491	1808.7±15438	970.2±1305.0	1438.6±1491	-	-	-
< Rs. 1000	142(24.3%)	(15.7%)	104(30.3%)	142(24.3%)	-	-	-
Rs 1,000 – 2,000	126(21.5%)	94 (38.8%)	32 (9.3%)	126(21.5%)	-	-	-
Rs. 2,000 – 3,000	35(6.0%	31(12.8%)	4 (1.2%)	35(6.0%)	-	-	-
> Rs. 3000	38(6.5%)	32(13.2%)	6 (1.7%)	38(6.5%)	-	-	-
Knowledge level	3.14±2.4	3.0±2.4	2.95±2.4	2.99±2.4	3.9±2.4	3.9±2.3	3.88±2.3
Physical Activity Sedentary Moderate Heavy	 435(61.9) 91(12.9) 177(25.2)	 99(40.9) 68(28.1) 75(31.0)	 223(65.0) 21(6.1) 99(28.9)	 322 (55.0) 89 (15.2) 174 (29.7)	 26(45.0) 17(30.0) 14(25.1)	 34(55.0) 18(30.0) 9(15.2)	 60(50.8) 35(29.7) 23(19.5)
Smoking/Tobacco	85(12.1)	85(35.1)	1(0.3)	86±12.1	0(0)	0(0)	0
Alcohol Intake	52(7.4)	51(21.1)	1(0.3)	52±7.4	0(0)	0(0)	0
CHO (gm)	298.24 (134.5)	334.70 (156.4)	287.77 (116.5)	307.2±136.3	261.8 (121.4)	246.49 (111.4)	253.8±116.2
Protein (gm)	63.83 (29.1)	72.98 (35.0)	61.03 (25.1)	65.9±30.2	55.54 (19.54)	51.02 (20.3)	53.2±20.0
Fat (gm)	15.90 (13.2)	18.71 (15.1)	13.97 (11.5)	15.9±13.3	17.59 (13.4)	14.0 (11.7)	15.7±12.6
Total Calories	1591.4 (667.8)	1799.17 (784.9)	1520.9(574.9)	1636.1±683.1	1427.7 (572.1)	1316.1 (499.1)	1370.0±536.2
< 1,000 Kcal	116(16.5%)	27(11.2%)	55(16.0%)	82(14.0%)	14(24.6%)	20(32.8%)	34(28.8%)
1,000 – 2,000 Kcal	444(63.2%)	146(60.3%)	227(66.2%)	373(63.8%)	34(59.6%)	37(60.7%)	71(60.2%)
2,000 – 3,000 Kcal	111(15.8%)	48(19.8%)	52(15.2%)	100(17.1%)	8(14.0%)	3(4.9%)	11(9.3%)
> 3,000 Kcal	32(4.6%)	21(8.7%)	9(2.6%)	30(5.1%)	1(1.8%)	1(1.6%)	2(1.7%)
Fiber (gm)	5.52 (2.9)	5.71 (3.07)	5.49 (2.83)	5.58±2.93	4.97 (2.8)	5.50 (2.65)	5.24±273

IFG = Impaired fasting blood glucose values

Data are presented as frequency (percent) or Mean±SD

*p < .05, ns = not significant; ** post prandial state = within 2 hours after the meal

† Total column includes individuals with normal, IFG, and Diabetes.

na = standards for Asian Indian youth are not available.

TABLE 2. Changes in Risk factors After DPM Intervention

Adults ≥ 18 years of age									
Variable	**Before**			**After**			**T-value (p-value)**		
	Total (n=703)	***IFG (n=79)***	***T2DM (n=30)***	***Total (n=703)***	***IFG (n=79)***	***T2DM (n=30)***	***Total (n=703)***	***IFG (n=79)***	***T2DM (n=30)***
	Mean±SD	***Mean± SD***	***Mean± SD***	***Mean±SD***	***Mean±SD***	***Mean± SD***			
Body Mass Index	20.6 ± 3.9	23.3±4.3	23.3±3.4	20.8±3.9	23.7±4.4	23.5±4.2	-2.87 (.004)	-2.27 (.026)	-.486 (.630)
Waist Circumference	29.8± 4.1	33.1±4.2	33.4±4.3	28.0±4.3	31.2±4.8	31.5±4.7	14.66(.001)	5.05 (.001)	2.15 (.039)
Hip Circumference	34.6±3.5	36.8±3.6	37.3±3.7	33.3±3.5	35.7±3.7	36.1±5.1	13.68(.001)	4.53 (.001)	1.94 (.062)
Waist – Hip Ratio	0.86±.08	.90±.08	0.90±.10	0.83±.08	.87±.09	.87±.10	6.32 (.001)	3.04 (.003)	1.06 (.297)
Thigh Circumference	17.5±2.1	18.5±2.0	18.3±2.1	16.6±2.2	17.8±2.6	17.5±2.3	13.47(.001)	3.45 (.001)	2.39 (.023)
Systolic Blood pressure	121.8±17.1	129.2±15.8	132.9±18.5	120.1±18.5	123.5±15.5	129.7±22	1.98 (.048)	3.49 (.001)	0.72 (.477)
Diastolic Blood pressure	85.4±15.2	93.2±14.9	92.5±18.2	79.5±14.0	82.2±13.7	87.0±15.8	8.40 (.001)	5.58 (.001)	1.54 (.134)
Fasting Blood glucose	94.4±46.1	108.4±7.4	240.7±128	91.2±30.8	96.5±15.7	180.5±81.9	2.01 (.045)	7.08 (.001)	2.27 (.031)
% calories from CHO	74.7±6.3	73.4±6.5	75.77±5.4	74.6±6.2	73.4±6.7	76.74±4.1	-.424 (.671)	.018 (.986)	-.96 (.343)
% calories from Protein	16.0±2.4	16.4±2.9	16.58±2.7	15.7±2.0	15.6±2.1	16.68±1.4	-3.04 (.002)	2.10 (.039)	-.18 (.858)
% calories from Fat	4.0±2.9	4.6±2.6	7.63±5.12	4.3±2.9	4.9±3.1	6.57±4.36	-1.49 (.136)	-.78 (.436)	1.15 (.258)
CHO (gm)	307.1±136.2	285.3±106.5	251.8±96.1	310.5±112.0	341.3±115.1	260.3±78	-.487 (.626)	-3.41 (.001)	-.376 (.710)
Protein (gm)	65.9±30.1	63.5±25.7	53.8±18.7	65.2±23.9	72.122.8	56.6±17.0	-2.81 (.005)	-2.33 (.022)	-.588 (.561)
Fat (gm)	15.9±13.3	18.1±14.7	24.4±18.3	18.0±14.0	21.1±12.9	23.1±16.8	.468 (.640)	-1.40 (.164)	.374 (.711)
Total Caloric Intake	1636.1±683.1	1558.5±576.8	1442.4±498.6	1665.6±574.1	1844.0±538.3	1475.1±441.9	-.846 (.398)	-3.37 (.001)	-.272 (.787)
Dietary fiber Intake	5.5±2.9	5.4±3.1	5.50±2.2	6.2±3.5	6.6±3.3	7.74±4.43	-3.50(.001)	-2.61 (.011)	-2.61 (.014)
Knowledge score	2.9±2.3	3.3±2.5	3.63±2.4	3.9±2.4	4.7±2.4	4.57±2.3	-8.03(.001)	-4.50 (.007)	-1.78 (.085)
Youth 10-17 years of age									
Variable	**Before**			**After**			**T-value (p-value)**		
	Total (n=112)	***IFG (n=6)***	***T2DM (n=0)***	***Total (n=112)***	***IFG (n=6)***	***T2DM (n=0)***	***Total (n=112)***	***IFG (n=6)***	***T2DM (n=0)***
	Mean±SD	***Mean±SD***	***Mean±SD***	***Mean±SD***	***Mean±SD***	***Mean±SD***			
Body Mass Index	16.0±2.7	16.0±1.7	-	16.5±2.4	17.7±2.2	-	3.86 (.001)	-3.37 (.020)	-
Waist Circumference	24.4±2.9	24.5±3.6	-	22.7±2.5	23.0±3.3	-	6.84 (.001)	1.46 (.203)	-
Hip Circumference	29.1±3.3	29.5±4.2	-	28.1±3.1	28.84.2	-	5.22 (.001)	1.00 (.363)	-
Waist – Hip Ratio	0.8±0.0	18.3±.08	-	0.8±0.0	.80±.06	-	3.90 (.001)	1.163 (.297)	-
Thigh Circumference	15.3±1.8	16.5±2.1	-	14.5±1.8	14.7±2.4	-	4.59 (.001)	2.61 (.048)	-
Systolic Blood pressure	106.6±11.2	106.8±12.8	-	103.9±10.8	101.0±8.9	-	1.95 (.001)	.85 (.435)	-
Diastolic Blood pressure	72.71±9.2	76.7±9.8	-	69.5±8.6	71.7±7.5	-	2.90 (.004)	.76 (.482)	-
Fasting Blood glucose	81.3±9.6	104.5±7.94	-	82.2±10.5	86.0±10.9	-	-.817 (.416)	3.67 (.014)	-
% calories from CHO	73.1±7.8	104.5±7.9	-	74.1±7.7	74.2±6.4	-	-1.00 (.317)	-.689 (.522)	-
% calories from Protein	15.8±3.1	72.0±8.9	-	14.9±2.0	13.8±1.7	-	2.59 (.011)	1.371 (.229)	-

% calories from Fat	4.8±3.5	15.4±2.7	-	4.8±3.9	5.3±2.6	-	.040 (.968)	.162 (.878)	-
CHO (gm)	253.8±116.1	5.6±4.3	-	263.0±106.8	304.3±113.4	-	-.699 (.486)	-.053 (.960)	-
Protein (gm)	15.7±12.6	300.0±148.2	-	17.0±14.4	56.7±23.2	-	-.813 (.418)	.328 (.757)	-
Fat (gm)	53.2±20.0	18.8±13.6	-	53.3±22.9	19.8±10.1	-	-.056 (.955)	-.197 (.852)	-
Total Caloric Intake	1370.0±536.2	1617.9±622.1	-	1419.5±547.6	1621.8±543.9	-	-.766 (.445)	-0.10 (.992)	-
Dietary fiber Intake	5.2±2.7	7.3±3.3	-	5.7±3.9	6.3±5.1	-	-1.04 (.300)	.355 (.737)	-
Knowledge score	3.8±2.3	5.0±1.8	-	4.5±1.9	6.2±1.8	-	-2.51 (.013)	-1.12 (.315)	-

IFG = Impaired fasting blood glucose values; T2DM = Type 2 diabetes mellitus

Total column includes individuals with normal, IFG, and Diabetes.

TABLE 3. Analysis of Covariance on Study Variables by Normal, IFG, and T2DM for Adolescent and Adult Groups (n=703)

Adults ≥ 18 Years of Age (n=585)					
Variables	**Normal(n=476)**	**IFG(n=79)**	**T2DM(n=30)**	**F-value**	**p-value**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**		
Body Mass Index	20.14(3.57)	23.72(4.38)	23.50(4.28)	2.75	.064
Waist Circumference	27.29(3.83)	31.22(4.82)	31.57(4.75)	3.34	.036
Hip Circumference	32.80(3.08)	35.78(3.73)	36.17(5.14)	8.42	<.001
Waist-Hip Ratio	0.83(.07)	0.87(.09)	0.88(.10)	2.65	.07
Thigh Circumference	16.35(2.09)	17.77(2.62)	17.50(2.28)	6.04	.003
Systolic Blood Pressure	119.03(18.53)	123.47(15.53)	129.70(22.08)	1.57	.208
Diastolic Blood Pressure	78.6(13.81)	82.5(13.65)	87.00(15.79)	2.87	.057
Knowledge Score	3.74(2.40)	4.70(2.35)	4.57(2.28)	5.22	.006
% Calories from CHO	75.025.98)	73.366.72)	71.247.01)	4.67	.010
CHO (gms)	308.58(112.0)	341.34(115.0)	260.53(78.9)	6.13	.002
% Calories from Protein	15.73(2.05)	15.62(2.07)	15.47(1.71)	.265	.768
Protein (gms)	64.70(24.2)	72.10(22.8)	56.55(17.0)	5.27	.005
% Calories from Fat	4.10(2.90)	4.89(3.06)	5.90(3.58)	4.31	.014
Fat (gms)	17.20(13.89)	21.14(12.89)	23.07(16.83)	3.53	.030
Total Calories	1647.9(581.5)	1844.0(538.3)	1475.0(441.9)	5.92	.003
Total Fiber	6.06(3.51)	6.59(3.30)	7.74(4.43)	3.81	.023
Youth < 18 Years of Age (n=118)					
Variables	**Normal(n=112)**	**IFG(n=6)**	**T2DM(n=0)**	**F-value**	**p-value**
Body Mass Index	16.53(2.45)	17.66(2.16)	-	3.67	.058
Waist Circumference	22.7 (2.55)	23.00(3.28)	-	.061	.806
Hip Circumference	28.11(3.14)	28.83(4.16)	-	.304	.583
Waist-Hip Ratio	0.81(.06)	0.80(.06)	-	.099	.753
Thigh Circumference	14.53(1.83)	14.67(2.33)	-	.494	.484
Systolic Blood Pressure	104.11(10.94)	101.00(8.94)	-	.464	.495
Diastolic Blood Pressure	69.46(8.68)	71.67(7.52)	-	.220	.640
Knowledge Score	4.41(1.93)	6.17(1.83)	-	3.73	.056
% Calories from CHO	74.13(7.88)	74.22(6.40)	-	.007	.933
CHO (gms)	260.87(106.62)	304.31(113.37)	-	.643	.424
% Calories from Protein	14.98(2.04)	13.79(1.68)	-	1.99	.160
Protein (gms)	53.17(23.04)	56.71(23.15)	-	.048	.827
% Calories from Fat	4.83(4.01)	5.32(2.61)	-	.057	.812
Fat (gms)	16.95(14.67)	19.75(10.10)	-	.154	.695
Total Calories	1408.74(548.06)	1621.83(543.81)	-	.566	.454
Total Fiber	5.66(3.95)	6.31(5.11)	-	.078	.781